

# Variable Voltage Substation Electrical Fire

## *Environmental Radiological Assistance Directory*

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# Background

SLAC's original SLAC 3 km electron Linac was constructed in the mid-1960's

- Based upon 30, 100-m sectors, each of which has 8 klystrons (except at injectors) providing RF power to the accelerator

Mid-2000's Sectors 21-30 were separated from Sectors 0-20

- Sectors 21-30 got a new injector and provide electrons to the Linac Coherent Light Source (LCLS)
- Sectors 0-20 provide electrons to Facility for Advanced Accelerator Experimental Tests (FACET)
  - In 2016 the "guts" of Sectors 0-10 will be demolished and the space repurposed as LCLS-II (new cryogenic accelerator modules)
  - Sectors 11-20 are under discussion for additional experiments
  - Sectors 21-30 will remain as LCLS

Linac klystron AC power distribution system is essentially unchanged since the 1960's



# Klystron Gallery looking west (towards injector)

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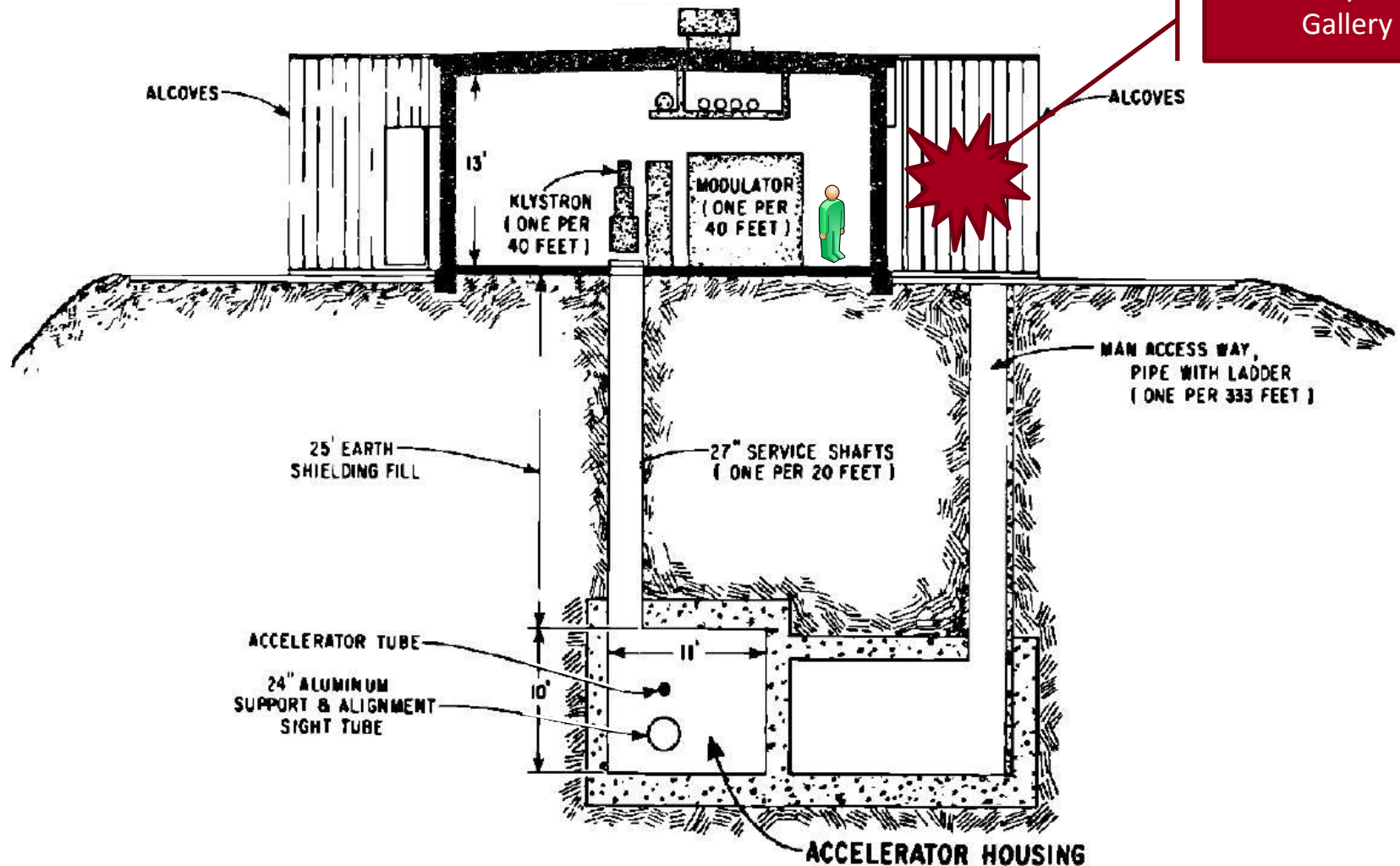
Outside

***Trivia:** the SLAC Klystron Gallery is, at 3073.72 m, the longest single-segment, non-fortification structure in the world.*

Inside

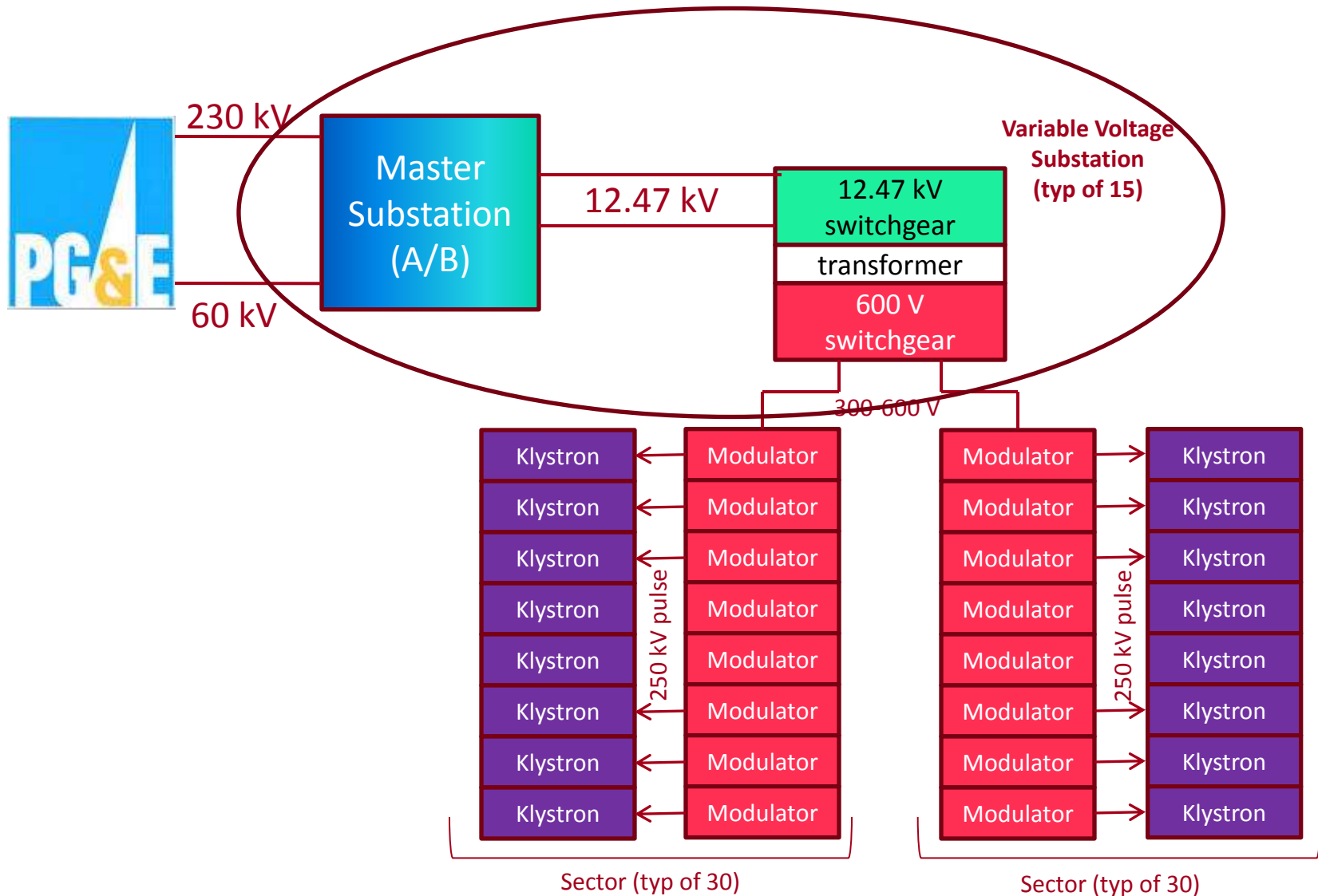


# Accelerator Housing and Klystron Gallery (cross section)



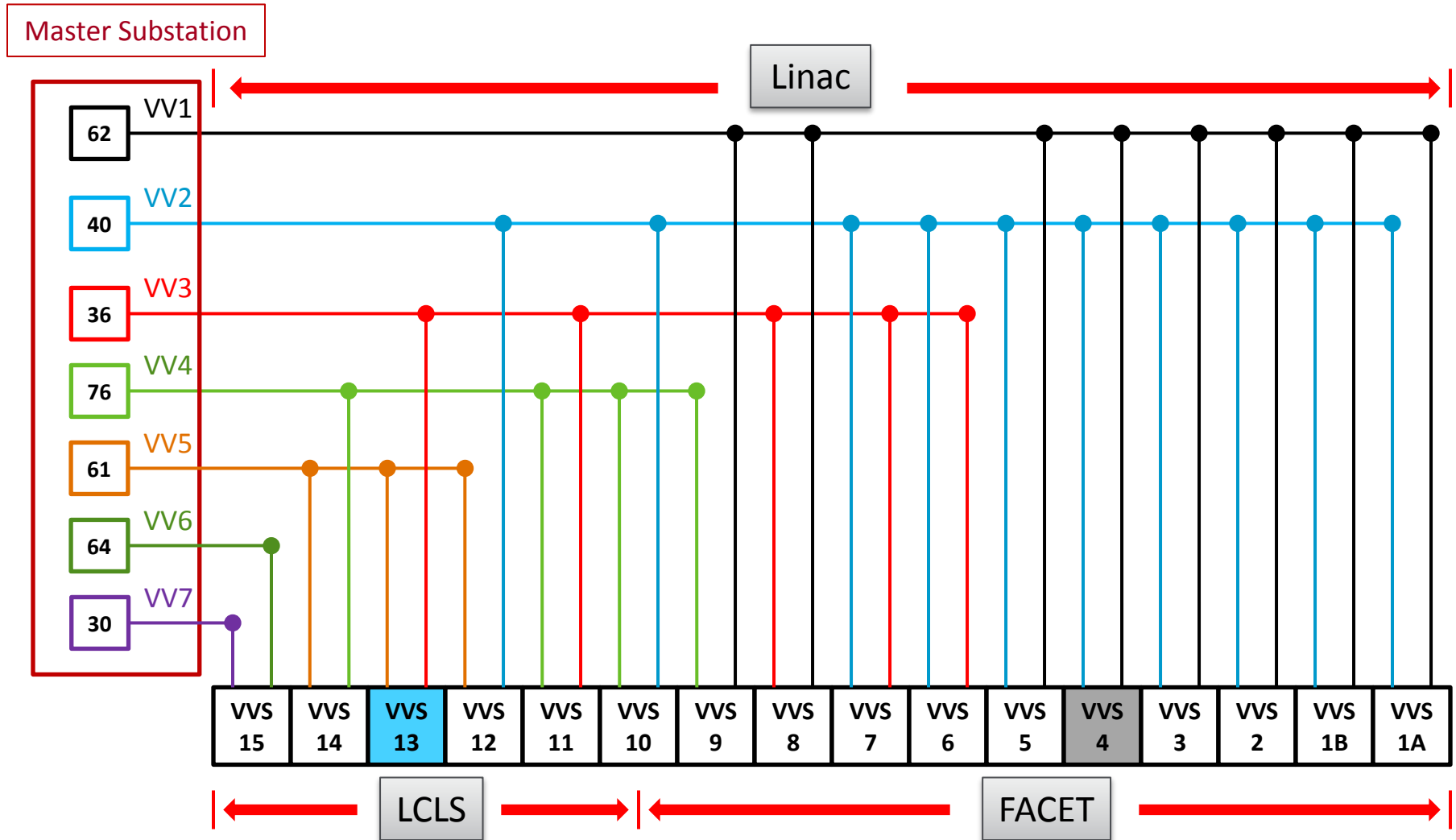
# AC Power Distribution to Linac Klystrons

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# 12.47 kV Power Distribution to VVS Subs

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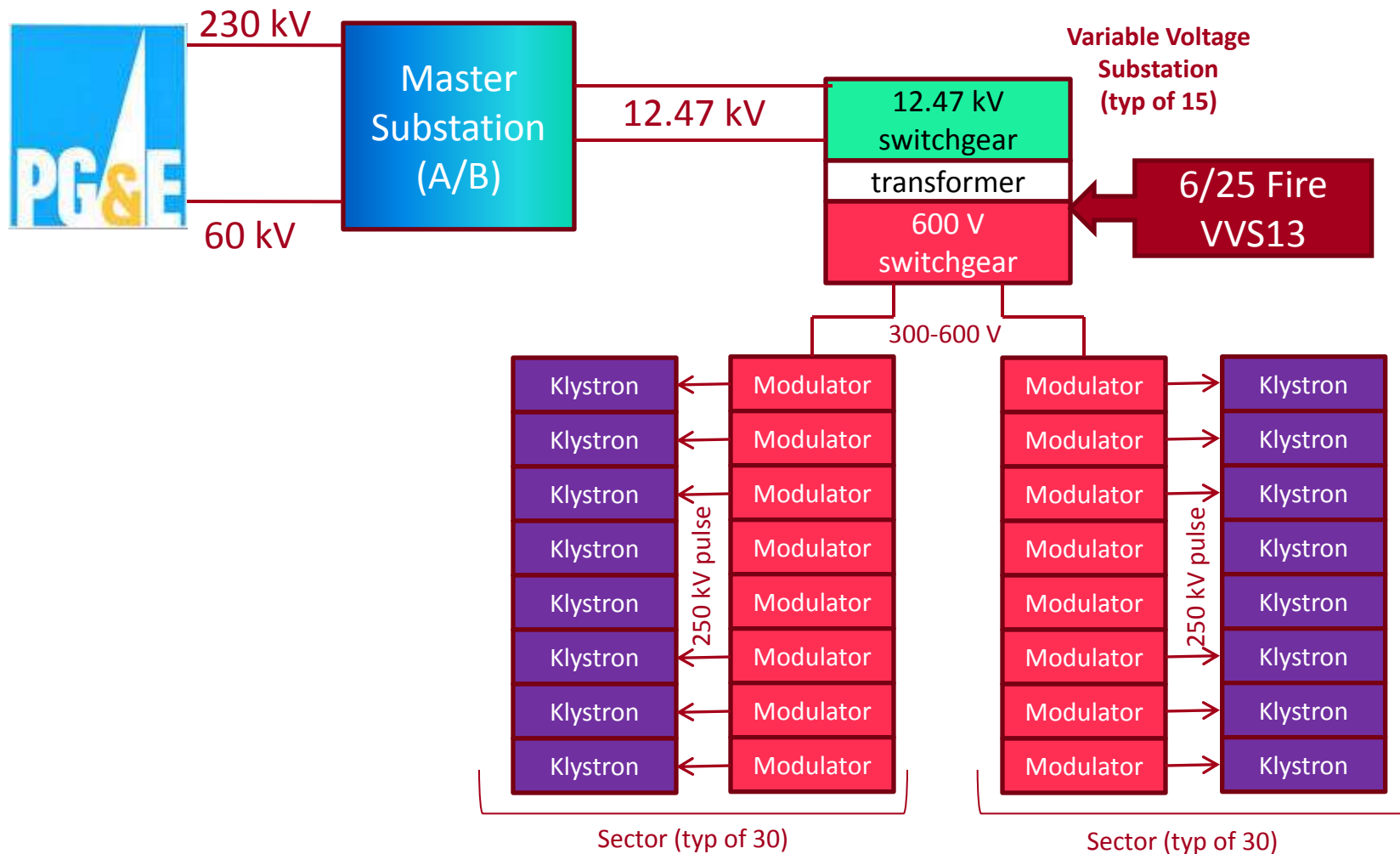
# Incident Response and Initial Assessment

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- 6/25 Wednesday – LCLS and FACET delivering beam to users
  - 2145 Accelerator Main Control Center noted VVS13 tripped. Vesda system alarmed. Onsite electrician reported that VVS13 was on fire.
    - Second alarm, 22 apparatus from sheriff and local fire departments responded
    - So did news crews from three local television stations
  - 2225 12kV locked off, suppression commences. EOC activated, notifications made.
  - 2300 fire is out
  - 2345 PPS is interrupted, locked out Linac East (Sectors 0-20)
- 6/26 Thursday
  - ~0200 EOC deactivated
  - News report went viral
  - During day: assess damage to 12kV



# AC Power Distribution to Linac Klystrons

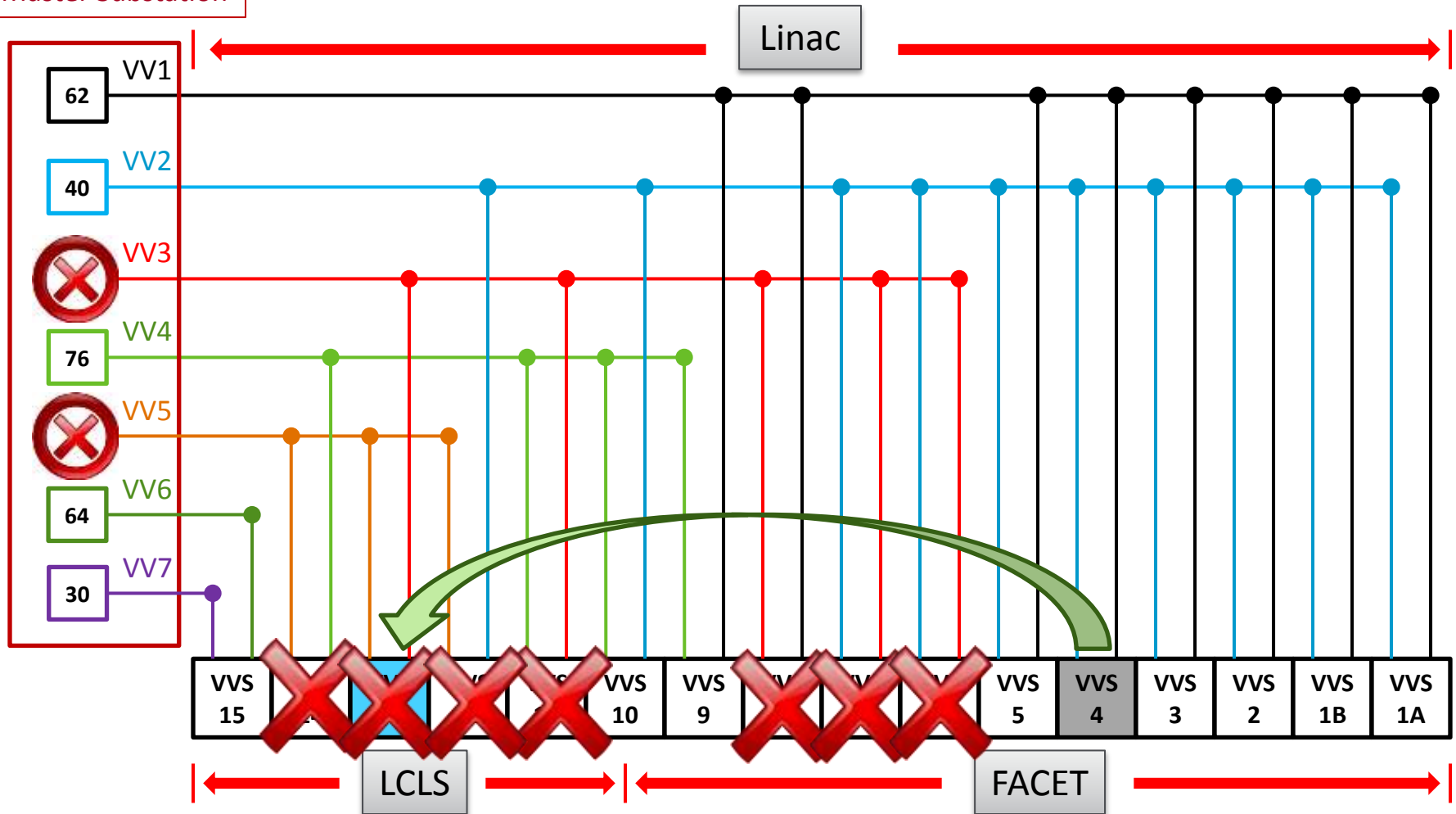




# 12.47 kV Power Distribution to VVS Subs

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Master Substation



# Typical Variable Voltage Substation (secondary side)

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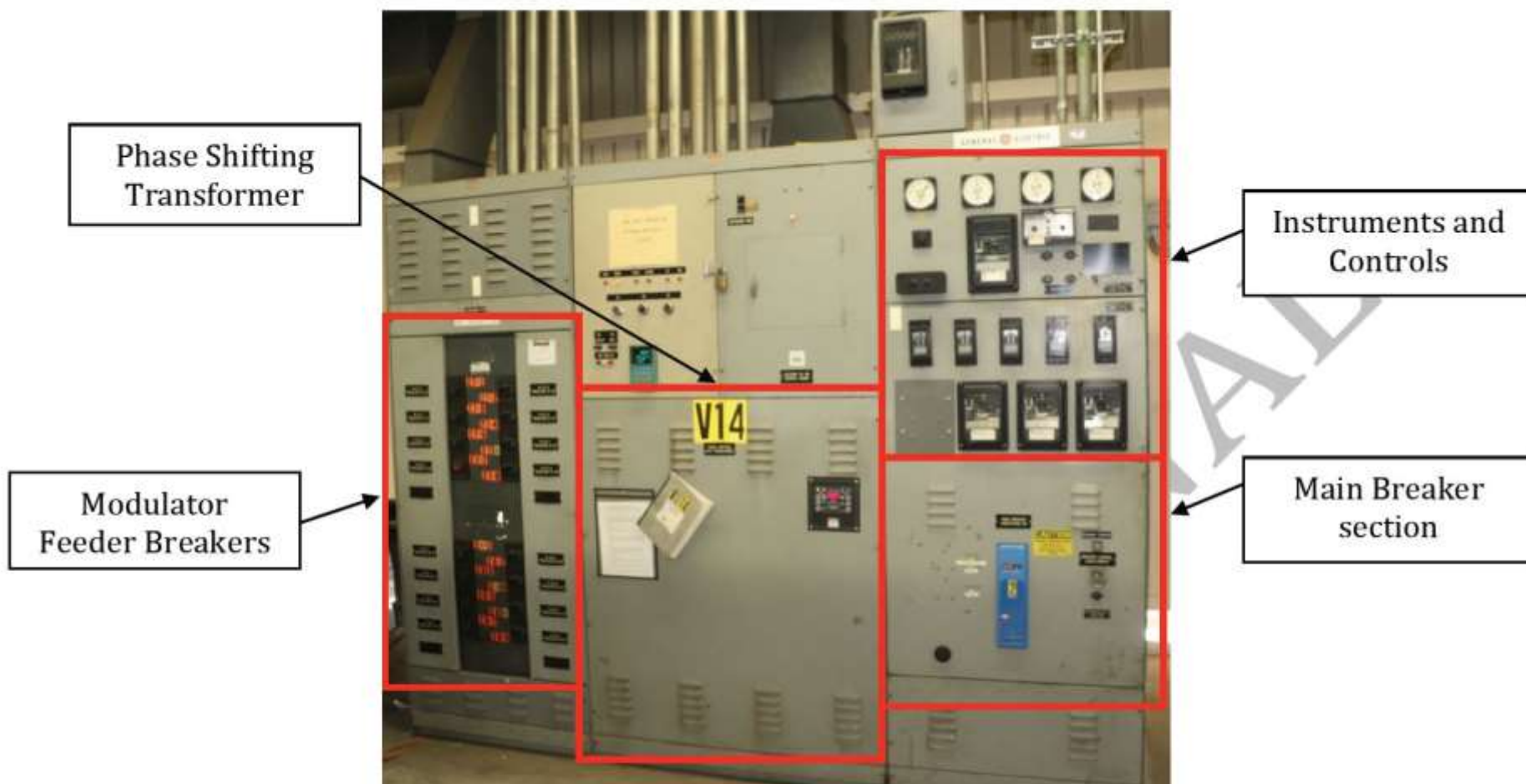


Figure 1. Photo of the secondary switchgear cabinet of a typical VVS.

# VVS13 After the Fire

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# Beam Recovery

- 6/26 Thursday
  - Inspect and test 12kV distribution lines
- 6/27 Friday
  - Inspect five other VVS on affected 12 kV legs, PPS bypass VVS13
    - Problems found with four of five other VVS, repair/replacements made
  - Restored 12kV ~1700, modulators ~2200
- 6/28 Saturday
  - Early am, LCLS and FACET user beams restored (LCLS at reduced power) *~50 hours user interruption*
- 6/30 Monday
  - Accepted subcontractor VVS replacement bid. Suspected asbestos in arc chutes, sampled debris
  - News of fire had become yesterday's news, little further interest
- 7/1 Tuesday
  - Asbestos confirmed, abatement crew brought in, begin prep of VVS4
- 7/4 Friday
  - Abatement completed, began installation of replacement VVS
- 7/9 Wednesday
  - VVS13 on line, full LCLS power restored, *~14 days recovery*

# Investigation and Analysis

- 6/30 Monday
  - Forensic investigation begun (subcontractor)
  - SLAC Root Cause Analysis (RCA) Investigation team charged
    - Six members from across laboratory (including one RCA specialist) plus one SLAC Site Office observer
    - Examine this incident and relate (if appropriate) to non-injury arc flash incident that occurred in March 2013 (VVS 1B, 12.47kV switch)
- 7/21 Monday
  - Draft forensic investigation report received
- 9/3 Wednesday
  - Final SLAC RCA Investigation report

# Conclusions

- Fire started as a result of an arc flash and ongoing electrical faulting between the input connectors of the secondary main breaker
- Unclear what started the arc flash. May have been high resistance, may have been contact with a displaced object within the cabinet. Downstream breaker may have contributed.
- Root Causes
  - Poor maintenance condition of VVS 13
  - Lack of effective stewardship of the VVS system by Facilities Department
- Contributing Causes
  - Fault protection systems inadequate
  - Lack of routine maintenance
  - Lack of condition assessment
  - Changes in operations increased frequency of breaker switching



# Judgments of Need

- Initiate an effective equipment stewardship program for critical infrastructure systems
- Define and evaluate critical electrical equipment for compensatory measures that could be implemented until full correction
- Evaluate all electrical and fire protective devices for adequacy to protect SLAC against risk and recommend upgrades
- Review circuit breaker use patterns to identify those with increased risk of failure
- Resolve all issues in a timely manner

# Accelerator Downtime VVS Condition Assessment

- Fire occurred in late June. Five of the six affected VVS secondary main breakers (including the one that burned) were not fit for service. VVS13 was destroyed, two repaired in place, two replaced.
- Extended planned accelerator downtime began on August 5
- All 14 operational VVS were inspected during extended downtime
  - Five additional secondary main breakers (total of eight/14) were found to be not fit for service and were removed (two previously repaired)
  - 68 modulator feeder breakers - ~25% - were found inoperative and were replaced
- During this downtime, additional protection to guard against this particular fault (low current, long duration) was designed and installed
- LCLS was brought up approximately on schedule early September
- FACET is on schedule for mid-October start

# VVS13 Repair - Replacement Project

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...containment

# VVS13 Repair - Replacement Project



...abatement complete, clearance received,  
containment removed, VVS removed.

# VVS13 Repair - Replacement Project

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...VVS4 riding down the gallery



# VVS13 Repair - Replacement Project



...VVS4 at its new home in S26



# VVS13 Repair - Replacement Project



...new modulator conductors readied for pull

# VVS13 Repair - Replacement Project

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...complete!!!

# Where do we go from here?

- Investigation reports are final
- Facilities Department is preparing Corrective Actions to address the causes and Judgments of Need (presentation 9/29), work already begun
- Right now we have no spare VVS
  - We do have designs and could have additional ones fabricated, but that likely would be weeks with that VVS station offline
  - After 2016 there will be spare VVS available from the demolition of Sectors 0-10 for LCLS-II

*Biggest single take-home message from this experience: keep up with the maintenance on your infrastructure. It will bite you if you don't!*

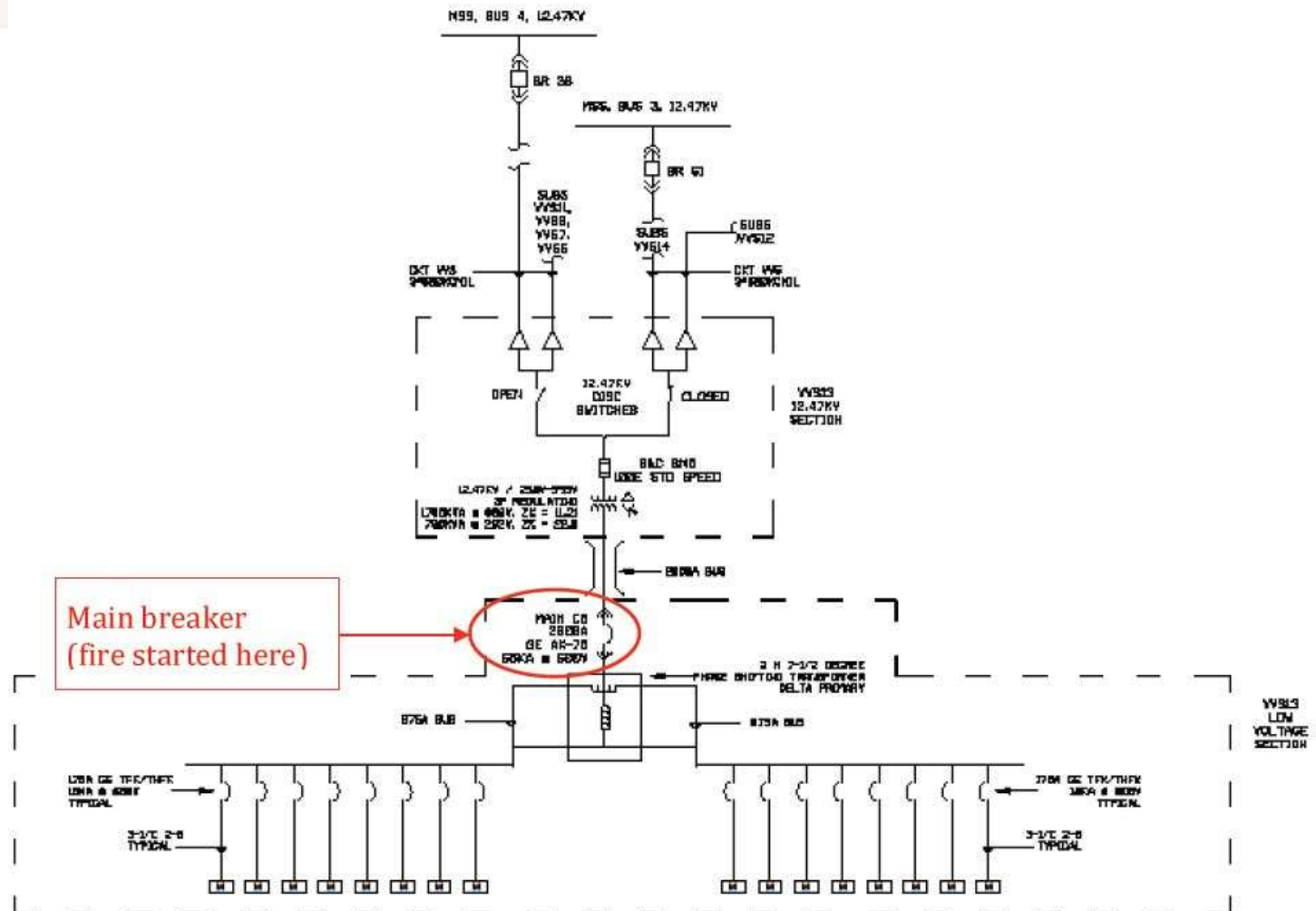
# QUESTION TIME!

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# One-line Diagram VVS-13



VVS13 SUB



